

IMPROVED THIN FILM TRANSISTOR ORGANIC LIGHT EMITTING DIODE STRUCTURE

FIELD OF THE INVENTION

[0001] The present invention relates to an electroluminescence (EL) display device, and more particularly to an EL display device comprising an EL element and a thin film transistor (TFT) that is employed as a switching element for the EL element.

BACKGROUND OF THE INVENTION

[0002] In a conventional EL display device, such as a TFT Organic Light Emitting Diode (TFT-OLED), one of the electrodes of the EL element contacts either the source or the drain electrode of the associated TFT device through a contact via hole in the underlying passivation layer. For example, schematically illustrated in Figure 1 is a cross-sectional view of a conventional TFT-OLED device. The TFT-OLED device is composed of a TFT device **100** and an OLED device **200** that are formed on top of a substrate **10**. The substrate **10** in this example is a semiconductor material and, thus, insulating buffer films **11** and **12** of silicon nitride and silicon oxide, respectively, are first formed on the substrate **10**. The substrate also may be formed of glass, synthetic resin, or the like also. In which case the buffer films **11** and **12** are not necessary.

[0003] The TFT device **100** is formed by first depositing an active layer **102** of a polysilicon film. The active layer **102** is doped on the outer sides to form a source **102S** and a drain **102D** regions with a channel region **102C** in between. A blanket of gate oxide insulation film **20** is then deposited over the active layer **102**, covering the active layer **102** as well as the rest of the substrate. A gate electrode **120**, typically of a chromium and molybdenum, is then deposited on the gate oxide insulation film **20** positioned directly over the channel region **102C**. Next, a blanket of interlayer dielectric (ILD) insulation layer **22** is provided, covering the gate electrode **120** and the rest of the gate oxide insulation film **20**. The ILD layer **22** is typically made from silicon nitride or silicon oxide. Via holes **111** and **112** are etched through the two insulation layers, ILD layer **22** and the gate oxide insulation film **20**, and down to the drain region **102D** and the source region **102S**. A drain electrode **110D** and a source electrode **110S** are formed by filling the respective via holes **111** and **112** with a metal such as aluminum. A first

passivation layer **30** is then provided over the entire surface covering the source and drain electrodes **110S**, **110D** and the necessary structures for the TFT device **100** is now fully formed.

[0004] The first passivation layer **30** forms the surface on which the OLED device **200** is formed. To form the OLED device **200**, a contact via hole **212** is first etched into the first passivation layer **30** over the source electrode **110S**. A transparent electrode constituting the anode **210** of the OLED is deposited on the surface of the first passivation layer **30** including the contact hole **212** so that the anode **210** makes electrical contact with the source electrode **110S** through the contact hole **212**. The anode **210** is made of a transparent electrically conductive material, typically indium-tin-oxide (ITO). A second passivation layer **32** is provided over the entire surface and an opening is etched into the second passivation layer **32** exposing the anode **210** in the region corresponding to the location of the OLED device **200** being formed. This opening defines a pixel in a display formed by a matrix of these EL display devices and an organic EL emitter layer **215** is deposited over the anode **210** in the opening region. Finally, a cathode **220**, typically of aluminum is deposited over the emitter layer **215** completing the OLED structure.

[0005] When an appropriate bias potential is created between the anode **210** and the cathode **220**, holes and electrons injected from the anode **210** and cathode **220**, respectively, are recombined in the emitter layer **215** causing the emitter layer to emit energy as light through the transparent anode **210** and the substrate **10**.

[0006] In the conventional EL display device, such as the conventional TFT-OLED structure illustrated in Figure 1, because the electrical contact between the anode **210** of the EL element and the source electrode **110S** is made through the contact hole **212**, which is small, the contact resistance tends to be high. Typically, the contact holes **212** are about 5 – 10 μm in diameter and the typical contact resistance between aluminum metal and ITO contacting through such a structure is about 50 ohms. This high contact resistance requires more power to drive the EL element. Improving the contact between the anode **210** and the source electrode **110S** and lowering the contact resistance would improve the EL display device's power demand.

[0007] Another problem with the conventional EL display device structure is that it is difficult to produce an anode layer having a desired flatness. Because the anode **210** of the EL element is deposited over a number of underlying layers of insulation films, it is difficult to control the surface roughness of the anode layer. For a reliable performance of the EL element, it is preferred that the anode **210** meet the flatness (or surface roughness) of $R_{ms} < 10 \text{ \AA}$ and $R_{pv} < 100 \text{ \AA}$.

[0008] Thus, an improved EL display device is desired.

SUMMARY OF THE INVENTION

[0009] According to an aspect of the present invention, an improved electroluminescence (EL) display device comprises a thin-film transistor (TFT) and an EL element successively formed on a substrate. The EL element may be a light emitting device such as an Organic Light Emitting Diode (OLED) and the TFT is used to drive the EL element. The substrate is transparent and may be formed of non-conductive materials such as glass, synthetic resin, or the like. It may also be formed of a semiconductor or conductive material, in which case, the substrate is passivated with one or more insulating films of silicon oxide or silicon nitride before the TFT device and the EL element are formed on the substrate.

[0010] The basic structure of the TFT is same as the conventional TFT device of Figure 1 and includes a source electrode, a drain electrode, and a gate electrode. But, in this embodiment of the present invention, the gate oxide insulation film and ILD layer extending into the EL element area are removed so that the anode of the EL element can be deposited directly on the substrate. Before the anode is deposited, the source electrode is deposited first so that a portion of the source electrode is disposed directly on the substrate. Alternatively, the drain electrode may be the one that has a portion disposed directly on the substrate.

[0011] The EL element includes a transparent anode layer, a cathode layer and an EL emitter layer disposed between the anode and the cathode layer. These layers are deposited on the substrate with anode directly on the substrate first, EL emitter layer on the anode, and the cathode deposited on the EL emitter layer.

[0012] Next, the EL element's anode is deposited on the substrate so that a portion of the EL element's anode overlaps and enshrouds the portion of the TFT's source electrode that is directly on the substrate. An important feature of this resulting structure is that the TFT's source electrode and the EL element's anode contact each other at the overlapping region without any intervening structure or materials therebetween. During the process of forming the TFT on the substrate, the source electrode is deposited with a portion directly on the substrate. The EL element's anode is, then, deposited on the substrate near the TFT so that an edge portion of the anode overlaps the source electrode and enshrouds an edge surface of the source electrode. The anode contacts the edge surface and the top surface of the source electrode. The result is that the contact area between the anode and the source electrode is larger than the contact made through a contact via hole in the conventional structures. Hence, the contact resistance between the anode and the source electrode is lower and, in turn, lowering the power demand of the EL display device. In another embodiment of the present invention, the order of depositing the EL element's anode and the TFT's source electrode may be reversed. The EL element's anode may be deposited first on the substrate and the TFT's source electrode is deposited with a portion directly on the substrate and overlapping the EL element's anode.

[0013] In yet another embodiment of the present invention, at least one of the gate oxide insulation film and the interlayer dielectric (ILD) insulation layer of the TFT device remains intact under the EL element. The TFT's source electrode and EL element's transparent anode are deposited on top of one of the insulation film layers rather than the substrate.

[0014] It would be obvious to one of ordinary skill in the art that the designations, source and drain, for the TFT electrodes are related to their electrical functionality in a given configuration and they may be reversed. This, in turn, also applies to the functional designations, anode and cathode, for the EL element. These designations for the electrodes may be reversed without deviating from the spirit of the present invention. Thus, in another embodiment of the present invention, the EL element's transparent electrode layer may be its cathode and the overlapping contact discussed above may be formed between the EL element's cathode and the TFT's drain electrode.

BRIEF DESCRIPTION OF THE DRAWING

[0015] The invention will be better understood from the following detailed description of an exemplary embodiment thereof in conjunction with the accompanying drawing in which:

[0016] Figure 1 is a schematic cross-sectional view of a conventional EL display device;

[0017] Figure 2 is a schematic cross-sectional view of an improved EL display device according to an embodiment of the present invention;

[0018] Figure 3 is a schematic cross-sectional view of an improved EL display device according to another embodiment of the present invention; and

[0019] Figure 4 is a schematic cross-sectional view of the contact region between a TFT's source electrode and an EL element's anode according to another embodiment of the present invention.

[0020] Same reference numerals are used to denote like parts throughout the various figures.

DETAILED DESCRIPTION

[0021] Referring to Figure 2, an improved electroluminescence (EL) display device according to an embodiment of the present invention is disclosed. The EL display device comprises a thin-film-transistor (TFT) and an EL element **200** formed on a substrate **10**. The EL element in this embodiment is an organic light emitting diode and the TFT is used to drive the EL element **200**. The substrate **10** is transparent and may be formed of a non-conductive material, such as, glass, synthetic resin, or the like. It may also be formed of a conductive or semiconductor material, in which case, the substrate **10** is usually passivated with one or more insulating films of silicon oxide and silicon nitride before the TFT **100** and the EL element **200** are formed on the substrate.

[0022] The TFT **100** in this embodiment of the present invention has the same structure as the TFT device in the conventional EL display device illustrated in Figure 1. But, after the source/drain electrodes **110S** and **110D** are deposited on the ILD layer **22**,

rather than covering the TFT structure with a passivation layer, the EL element's anode **210** is deposited directly on to the ILD layer **22** so that both the TFT's source electrode and the EL element's anode **210** are deposited on the ILD layer **22**. The EL element's transparent anode **210**, typically of indium-tin-oxide (ITO), is deposited on the ILD layer **22** so that an edge portion **213** of the anode **210** overlaps and enshrouds the portion of the source electrode **110S** that is deposited directly on the ILD layer **22**. The source electrode **110S** has an edge surface **115** and a top surface **116** that directly contact the EL element's anode **210**. In other words, the anode **210** and the edge surface **115** and the top surface **116** make a contact without any intervening layers so as to maximize the contact area among these surfaces. The contact formed between the anode's edge portion **213** and the source electrode **110S** has a substantially larger contact area than the contact formed through the contact hole **212** in the conventional EL display device illustrated in Figure 1. Because of the larger contact area, the electrical contact resistance between the EL element's anode **210** and the TFT's source electrode **110S** is lower, resulting in a lower power demand. Although this embodiment of the present invention is illustrated with the source electrode **110S** having two distinct surfaces, the edge surface **115** and the top surface **116**, the edge of the source electrode **110S** may have many variety of surface configuration depending on the needs of the particular application without deviating from the spirit of the present invention.

[0023] Subsequently, a blanket of passivation layer **30**, typically of silicon nitride is deposited covering the TFT's source and drain electrodes **110S** and **110D**. A portion of the passivation layer **30** over the EL element's anode **210** is removed exposing a portion **211** of the anode **210**. The EL element **200** is completed by depositing an emitter layer **215** of an organic compound and a cathode layer **220** of an opaque electrically conductive material such as aluminum.

[0024] Referring to Figure 3, an improved EL display device according to another aspect of the present invention is disclosed. In this embodiment of the present invention, the gate oxide insulation film **20** and the ILD layer **22** are removed from the EL element region by an appropriate etching process so that the EL element **200** can be formed directly on the substrate **10**. In this embodiment of the present invention, the substrate **10** is a semiconductor and, thus, its surface is insulated with insulation buffer films **11** and

12 of silicon nitride and silicon oxide, respectively. If the substrate **10** were non-conductive material such as glass, the buffer insulation layers **11** and **12** would not be necessary and the EL element **200** may be formed directly on the substrate **10**.

[0025] After the gate oxide insulation film **20** and the ILD layer **22** are removed from the EL element region of the substrate, the source electrode **110S** and the drain electrode **110D** are deposited. As illustrated, the source electrode **110S** is provided over the source **102S** and extends towards the EL element region and down to the exposed insulation buffer film **12** so that a portion of the source electrode **110S** is directly deposited on the insulation buffer film **12** (or the substrate **10** if the buffer films are not used). Next, the EL element's transparent anode **210** is deposited on the substrate's insulation buffer film **12** with an edge portion **213** of the anode **210** overlapping the portion of the source electrode **110S** that is sitting directly on the insulation buffer film **12**. The anode's edge portion **213** enshrouds the source electrode's edge surface **115** and top surface **116**. The contact thus formed between the anode **210** and the source electrode **110S** has a lower electrical contact resistance than that of the conventional EL display device illustrated in Figure 1.

[0026] The TFT **100** and the EL element **200** are then completed by depositing the passivation layer **30**, the emitter layer **215** and the cathode layer **220**, successively in that order, as described above in reference to the embodiment of the present invention illustrated in Figure 2.

[0027] In the various embodiments of the present invention described above, it should be noted that the order of depositing the TFT's source electrode **110S** and the EL element's anode **210** may be reversed. Illustrated in Figure 4 is the resulting structure where the anode **210** is deposited first on the substrate **10** and the source electrode **110S** is subsequently deposited over the anode enshrouding the edge portion of the anode **210**.

[0028] While the foregoing invention has been described with reference to the above embodiments, various modifications and changes can be made without departing from the spirit of the invention. Accordingly, all such modifications and changes are considered to be within the scope of the appended claims.